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CLIMATE CHANGE, SOIL TEMPERATURE AND CASSAVA YIELD IN ABIA STATE, SOUTHEASTERN NIGERIA

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ABSTRACT

The climate of the world is changing and consequently affecting other components of the earth-atmosphere system. The extent to which it is affecting soil temperature in relation to cassava yield has not received the deserved attention especially in Abia State where it is a major staple crop. This paper therefore examined the effect of climate change on soil temperature and cassava yield in Abia State. Climatic data of rainfall, atmospheric temperature and soil temperature(20cm depth) covering a period of 34 years and those of cassava yield for 31 years in Abia State were collected. Regression and Correlation statistics were the major techniques used to model trends and establish relationships in the data. Results obtain indicated that rainfall of Abia State is getting wetter at a rate of 1.619mm per annum, mean annual atmospheric temperature is increasing by 0.025℃ annually, soil is warming at a rate of 0.023℃ per annum, while cassava yield is increasing by 16.05 thousand metric tonnes per annum. There is also a high correlation between soil temperature and cassava yield. These results obtained therefore suggest that following climate change, soil temperature is correspondingly increasing, and so also is cassava yield.

KEYWORDS: Climate Change, Atmospheric Temperature, Soil Temperature, Cassava Yield

INTRODUCTION

Climate change, which could mean any marked departure from an initial climate due to a sustained trend in any climatic element over a long period of time not less than 30 years (Nwagbara, 2008), is now one of the most actively investigated scientific issues due to its potentially far-reaching consequences(IPCC, 1996; Danielson *et al*., 1998). It is being driven by the warming of the globe, popularly tagged 'global warming'. Global warming itself has carbon dioxide as its chief driver (IPCC, 2001) followed by water vapour, chlorofluorocarbons (CFCs), methane, tropospheric ozone, and nitrous oxide. These gases are termed greenhouse gases as they are relatively transparent to solar radiation but absorb and emit terrestrial radiation, thereby increasing atmospheric temperature. What this brings about and its extent varies from region to region. It could be negative for some, and for others positive or a combination of both. Africa has been considered to be the world's most vulnerable region with regard to climate change due to the fragility of economies (IPCC, 2007). Incidentally, the concentration of the greenhouse gases in the atmosphere is on the increase (IPCC, 2013) which implies greater warming and further change in climate. Temperature is not only an element of weather and climate but also a factor of climate. This means that a change in it could bring about a change in some other elements of weather and climate thus reasonably determining climate and by extension the other components of the earth atmosphere system (for example, soil).

Soil possesses temperature which is referred to as soil temperature. This temperature is very important in the growth and development of crops because of its roles in the soil. Soil temperature is known to control biogeochemical

processes such as dissolved organic carbon (Zhang *et al*., 2005). It also controls rates of mineralization of decomposition of soil organic matter and nutrient assimilation by crops, the weathering of base cat ions, forest productivity and length of growing season (Eukirchen *et al*., 2006) and even seed germination and tuber formation for tuber crops. Root respiration has been found to increase with rising soil temperature (Atkin *et al*., 2000). This is because of the higher availability of carbohydrates from enhanced photosynthesis which provides more energy for active transport. Soil temperature being atmospheric temperature dependent, could therefore be affected by the on-going climate change. In Canada, the warming trend in soil temperature has been associated with trends in air temperature and snow cover depth over the period (Qian *et al*., 2011). This could also be true for Nigeria with its attendant affects on crops including cassava.

Cassava (*Manihot Esculenta* Crantz) is an important and common primary staple or secondary co-staple food an cash crop for many in tropical and subtropical regions, and is extensively cultivated as an annual crop for its edible starchy tuber. In most parts of Nigeria (a typical tropical country), including Abia State (the study area) cassava plays a principal role in food economy. It thrives well even in extreme conditions of drought (Awa and Tumanteh, 2001).

Planting depth of cassava is between 5 and 20cm (IITA, 2014). It roots or tubers sometimes radiate from the stem just below the surface of the ground through the feeder roots penetrate the soil to a depth of 50 to 100cm (FAO, 1977), cassava yield and productivity are influenced, among other factors, by soil temperature. Environmental factors such as soil temperature, moisture and nutrients affect root respiration (Sahney *et al*., 2010). From the time of planting cassava stems to the stage of tuberization, soil temperature has one role or the other in to play in the crops growth. Very high soil temperature may mean cooking the planted stems or the tubers depending on the crop’s stage while very low soil temperature could mean inactivity for the crop at whatever stage that happens. Cassava grows best when the soil temperature is about 30℃ and stops growing when it is below 10℃(FAO/IFAD, 2001).

Incidentally, the role of soil temperature in the growth of cassava notwithstanding, it has not received as much attention as other climatic variables such as sunshine atmospheric temperature and precipitation. The need to do a study in this direction becomes compelling especially in Abia State, Southeastern Nigeria where cassava is not only popular but an important staple food and cash cropping. This paper therefore examines the extent climate of Abia State is changing, and the extent to which the change is impact on soil temperature and cassava yields in the area.

AREA DESCRIPTION

The study area is Abia State, Southeastern Nigeria. It lies between latitudes 4° 40' and 6°14' N and longitudes 7° 10' and 8° 00’ E (Figure 1). This very location makes it a typical humid tropical region where annual rainfall total is about 2141 mm and a relative humidity ranging between 60 and 90% with two marked seasons namely rainy season (April to October) and dry season (November to March). The mean annual temperature is about 26.5℃ where the mean annual minimum temperature is about 21.8℃ where the mean annual maximum temperature is 31.2℃. And the mean annual soil temperature is 28.6℃.

The state had a population of 2,833,999 in 2006 (NPC, 2007). With the land of 6320km^2 it implies a population density of about 448 persons per km for Abia Stateas at 2006. Over seventy percent of this population is involved in agriculture as occupation (Abia State Government, 2011). Food crops majorly cultivated include cassava, yam, rice, plantain and maize. Of these crops, cassava is the most popularin homes in Abia State

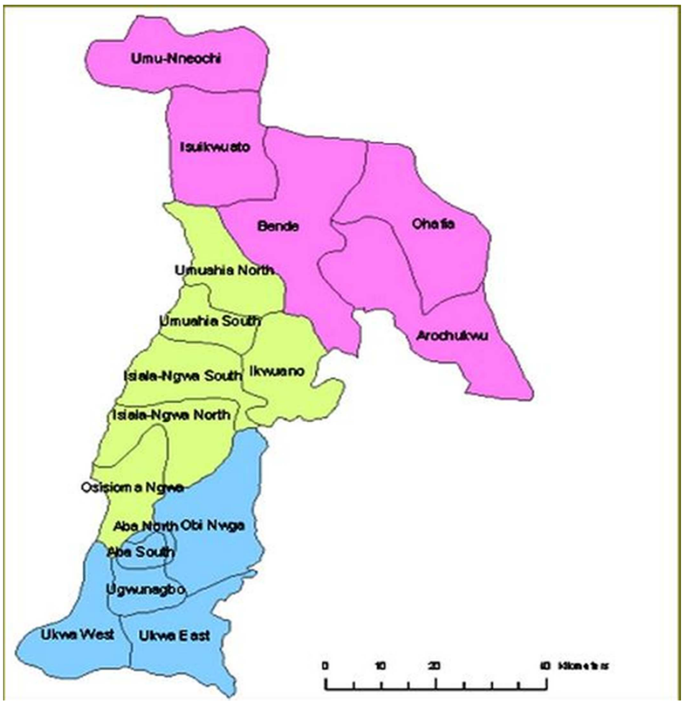

Figure 1: Abia State: Study Area

owing to the several food items that are produced from it. Such food items include garri (or eba), fufu (or akpu) and tapioca for man. Cassava is also processed into chips and pellets for livestock and fish.

MATERIALS AND METHODS

Data Used

Climatic data on monthly minimum and maximum atmospheric/air temperatures, monthly rainfall totals and monthly soil temperatures, monthly rainfall totals and monthly soil temperature at a depth of 20cm covering a period of 34 years (1980 to 2013) were collected from the Agro-meteorological unit of the National Root Crops Research Institute, Umudike, Abia State, Nigeria. Data on annual cassava yield of Abia State covering a period of 31 years (1980 to 2011) were collected from the State Agricultural Development Programme (ADP), Umuahia, Abia State.

The monthly minimum and maximum temperatures were first transformed to mean annual minimum and mean annual maximum temperatures. Then, the two further transformed to mean annual temperatures. The monthly soil temperatures were equally transformed to mean annual soil temperatures while the monthly rainfall totals were also transformed to annual rainfall totals.

Temperature and rainfall were used as indicators of climate change as they are not only elements of weather and climate but also factors of climate with the implication that any change in them will likely cause change in the other elements. The 20cm depth for the soil temperature was chosen because cassava is generally a shallow crop as stem planting depth, tuberization and most feeder roots are within the 20cm depth. Equally, the periods covered by the data used are considered to be periods with available and reliable data to minimize errors resulting from estimating missing values.

DATA ANALYSIS

Regression and correlation were the major statistical techniques used in analyzing the data collected. The least squares regression equation was used in modelling the trends in the parameters namely, rainfall, air temperature, soil

temperature and cassava yield data. It is expressed in the form:

$$y = a + bx \tag{1}$$

Where

$$b = \frac{n\sum xy - (\sum x)(\sum y)}{n\sum x^2 - (\sum x)^2} \tag{2}$$

And

$$a = \frac{\sum y}{n} - \frac{b\sum x}{n} = \bar{y} - b\bar{x} \tag{3}$$

a is the intercept; b the regression coefficient or slope; y the parameter values; x the time in years; $\bar{x}$ the meantime;$\bar{y}$the mean parameter values; and n is the number of observations in the parameters.

The Pearson's Product Moment Correlation Coefficient (r) was employed to examine the degree of association between time and the values of parameters and between soil temperature and cassava yield. It can be written as:

$$r = \frac{n\sum xy - (\sum x)(\sum y)}{\sqrt{n\sum x^2 - (\sum x)^2}\sqrt{n\sum y^2 - (\sum y)^2}} \tag{4}$$

Where n, x and$y$ are as in equation 1, 2 and 3

Coefficient of determination (C/D) was applied to determine what percentage of variation in each parameter value is explained by time, and the variation in cassava yield explained by soil temperature,

C/D = r^2 x 100% - (5)

Where r is as in equation 4

To test for significance of the correlation coefficient, the student 't' test was utilized. It is given as:

$$\text{Student't' test} = \frac{r\sqrt{n-2}}{\sqrt{1-r^2}} \tag{6}$$

Where r is as in equation 4 and n is as in equations 2, 3 and 4.

RESULTS AND DISCUSSIONS

The results obtained from the application of the linear regression statistical technique to the four parameters are presented in table 1.

Table 1: Prediction Models for Parameters Analyzed for Abia State

S/N	Parameter	Period	a(Intercept)	a(Slope)	Regression Line Equation
1	Annual rainfall total	1980-2013	2127	1.619x	Y = 2127+1.619x
2	Mean annual air temperature	1980-2013	26.46	0.025x	Y = 26.46+0.025x
3	Mean annual soil temperature (20cm depth)	1980-2013	28.22	0.023x	Y = 28.22+0.023x
4	Cassava yield	1980-2011	229.7	16.05x	Y = 229.7+16.05x

The results are further shown in figures 2, 3, 4 and 5 where trend lines were fitted through the fluctuations in the parameters during the periods studied. Each of these figures tells about the linear relationship between the parameters and time and that between soil temperature and cassava yield. Common among these parameters as indicated in figures 2, 3, 4 and 5 is the possession of positive trend by them, though not at the same rate. While the rainfall of Abia Stateis increasing at a rate of 1.619 mm per

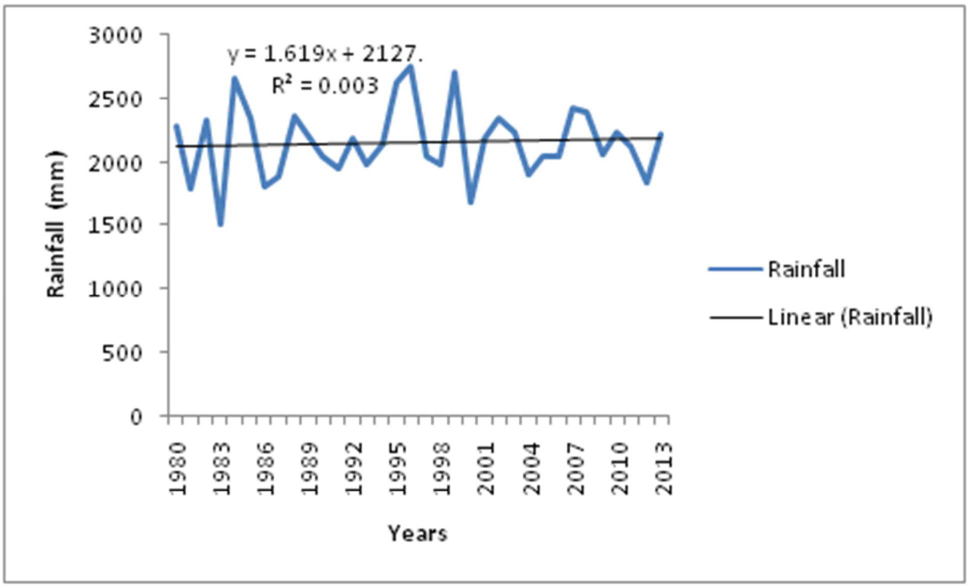

Figure 2: Linear Trend of Annual Rainfall Totals (1980 – 2013)

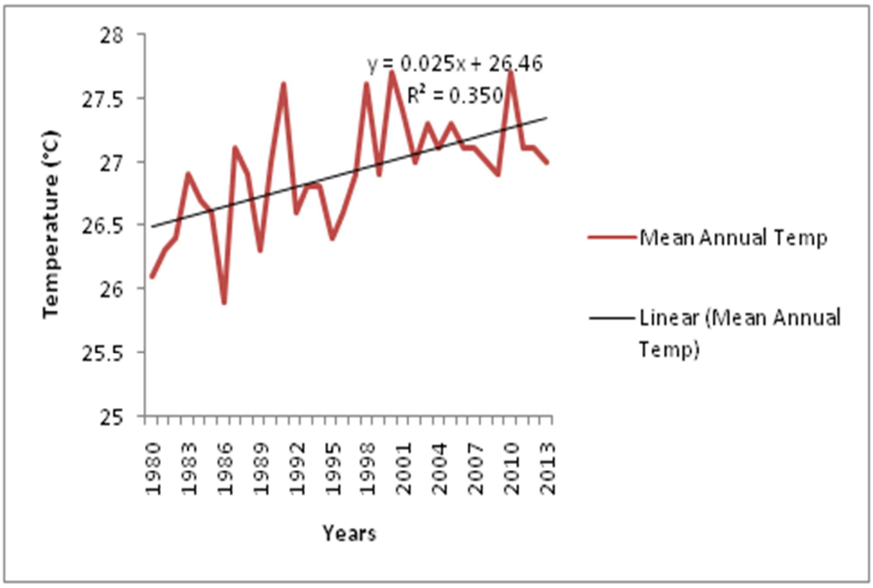

Figure 3: Linear Trend of Mean Annual Temperature (1980 – 2013)

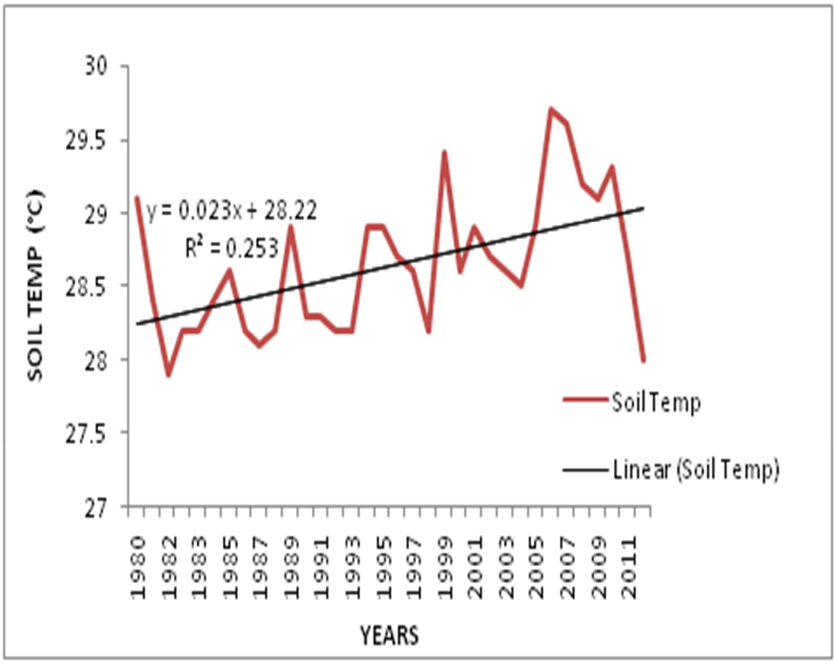

Figure 4: Linear Trend of Mean Annual Soil Temperature (1980 – 2013)

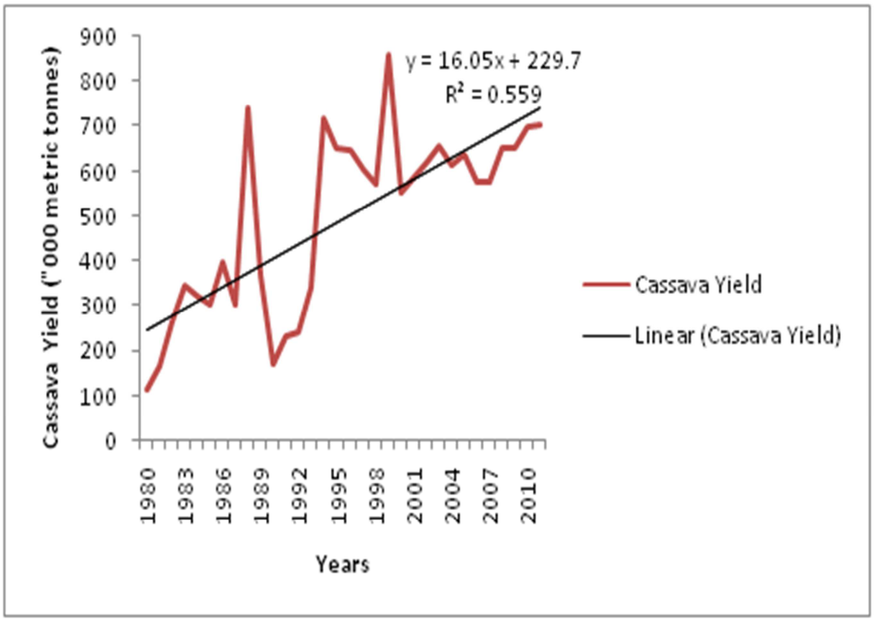

Figure 5: Linear Trend of Annual Cassava Yield (1980 – 2011)

annum, the state is getting warmer by 0.025°C annually; the soil temperature at 20cm depth is warming too but at the rate of 0.023°C annually whereas the cassava yield is increasing at a rate of 16.05 thousand tons per annum. These upward trends are generally gradual but steadyexcept for cassava yield which is dramatic.These trends are all significant at 95% level of confidence except that of rainfall (see table 2). The upward trend in air temperature is not surprising as it fits into the global trend where the globe is warming, (IPCC, 2001; USNCDC, 2001). The increasing rainfall is equally not surprising as increase in air temperature brings about increase in evapotranspiration, where wet surfaces exist, which encourages condensation, cloud formation and precipitation (Chima *et al*., 2009). Abia State is located in the tropical rainforest and has rivers and swamps within and around it and is less than 100km from the Atlantic Ocean thus making the

warming trend to encourage evapotranspiration and the end product, precipitation.

Similarly, air temperature being a major factor of soil temperature could be the major reason for the increase in soil temperature. (Bai *et al*., 2014) indicated a high correlation between temporal changes in soil temperature and those of air temperature. Possibly the soil temperature warming rate of 0.023℃ per annum would have been higher in pursuit of the air temperature value of 0.025℃ but not for rainfall which possesses an upward trend. Water in the soil acts as coolant, thus more of it in the soil would bring about more cooling implying reduction in soil temperature. However, the rainfall increase is gradual though steady thus making its moderating effect not to be overwhelming especially, as the air temperature, a major factor in soil warming, is also increasing.

Table 2: Correlation Coefficients, Coefficients of Determination and Significance at 95% Confidence Level for the Parameters Analyzed

Parameters Correlated	r (Correlation Coefficient)	r^2 (Coefficient of Determinant)	Calculated Value	Table Value	Result
Rainfall and time	0.06	0.003	0.37	1.70	Not significant
Air temperature and time	0.67	0.350	5.12	1.70	Significant
Soil temperature and time	0.50	0.253	3.25	1.70	Significant
Cassava yield and time	0.75	0.559	6.44	1.70	Significant
Cassava yield and soil temperature	0.75	0.559	6.08	1.70	Significant

The increase in cassava yield in Abia State during the study period may not be unconnected with the rising soil temperature as increase in mean annual soil temperature highly correlates with increase in annual cassava yield. Table 2 shows a coefficient of determination of 0.559, that is, 56% between soil temperature and cassava yield. This agrees with (Makinde and Bello, 2009) where increase in soil temperature enhanced cucumber yield by about 50%. Cassava has been reported to grow best at a soil temperature of about 30℃ (FAO/IFAD, 2001). Soil temperature in the study area hovers around 28.6℃ on average and is still increasing thus implying a steady and more increase in cassava yield in the area as a soil temperature increase of 0.023℃ is bringing about a cassava yield of 16.05 thousand tonnes per annum.

CONCLUSIONS

Abia State, Southeastern Nigeria is getting warmer and wetter as seen in figures 2 and 3. The warmer air is bringing about warmer soils and the warmer soils are in turn encouraging cassava yields (see figures 4 and 5), an important and popular cash and food crop of this area. Climate change is therefore positively impacting on the state in this direction. The over 70 percent of the area's population involved in agriculture and investors should take advantage of the prevailing warmer soils and increased rainfall to cultivate more and invest (for new ones) or invest more (for old ones) respectively in cassava production. This will not only increase food security but also improve the income of farmers and investors, thereby bringing about greater development of the state.

The Federal Government of Nigeria, Abia State Government and the local government areas of the state should therefore make the investment climate for cassava production conducive enough to local farmers and to attract investors. This they can do by providing affordable farmlands, farm inputs and adequate transportation, processing and storage facilities. As for the market, it is very readily available both locally and internationally.

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